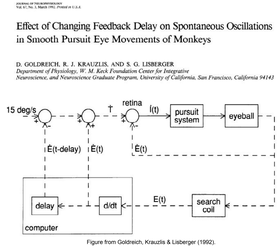
BACKGROUND

Delayed Visual Feedback



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Effect of Changing Feedback Delay on Spontaneous Oscillations in Smooth Pursuit Eye Movements of Monkeys

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Figure from Goldreich, Krauzlis & Lisberger (1992).

Theory

$e(t)$	eye position (EP)
$p(t)$	target position
$\dot{e}(t)$	eye velocity (EV)
$\dot{p}(t)$	target velocity
$\ddot{e}(t)$	eye acceleration (EA)
$\ddot{p}(t)$	target acceleration

$p(t) = k$	stationary target
$p(t) = e(t)$	ideal stabilization
$p(t) = e(t-\varepsilon)$	lab stabilization
$p(t) = e(t) + d(t)$	open-loop
$p(t) = e(t) - e(t-\delta_2)$	transient stabilization

$p(t) - e(t)$	retinal position error (RPE)
$\dot{p}(t) - \dot{e}(t)$	retinal velocity error (RVE)
$\ddot{p}(t) - \ddot{e}(t)$	retinal acceleration error (RAE)

$$\ddot{e}(t) = k_1\left[p(t-\delta_1) - e(t-\delta_1)\right] \quad \text{RPE drives EA}$$

$$\ddot{e}(t) = k_2\left[\dot{p}(t-\delta_1) - \dot{e}(t-\delta_1)\right] \quad \text{RVE drives EA}$$

$$\ddot{e}(t) = k_3\left[\ddot{p}(t-\delta_1) - \ddot{e}(t-\delta_1)\right] \quad \text{RAE drives EA}$$

$$\dot{e}(t) = k_2\left[p(t-\delta_1) - e(t-\delta_1)\right] \quad \text{RPE drives EV}$$

$$\ddot{e}(t) = k_2\left[\dot{p}(t-\delta_1) - \dot{e}(t-\delta_1)\right] \quad \text{RVE drives EA}$$

Predictions

$p(t) = e(t) - e(t-\delta_2)$ transient stabilization

$\ddot{e}(t) = k_1\left[p(t-\delta_1) - e(t-\delta_1)\right]$ RPE drives EA

$\ddot{e}(t) = k_1\left[e(t-\delta_1) - e(t-\delta_1-\delta_2) - e(t-\delta_1)\right]$

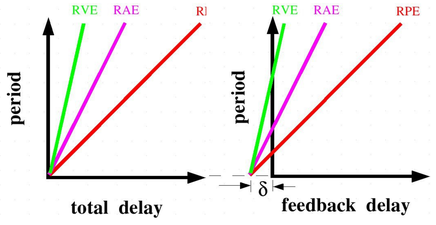
$\ddot{e}(t) = -k_1 e(t-\delta_1-\delta_2)$

$\ddot{e}(t) = -k_1 e(t-\delta)$

$\lambda = \delta$	RPE drives EA
$\lambda = 4\delta$	RVE drives EA
$\lambda = 2\delta$	RAE drives EA

$$\lambda = \frac{4\delta}{4n+2-N_d}$$

$\lambda = \frac{4}{3}\delta$ RPE drives eye jerk



Results

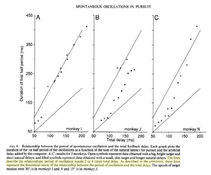
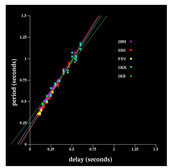


FIG. 4. Relationship between the period of spontaneous oscillation and the total feedback delay. Each graph plots the period of oscillation (ordinate) against the total delay (abscissa) for one monkey. Each point represents the mean of 5 trials at a single delay, pooled by data collected in the categories, A–C, shown in the 3 insets above. Dashed lines in the insets represent data obtained with no delay. Solid lines in the insets and in the main graphs represent data obtained with 100 ms of delay. Dashed lines in the main graphs describe the relationship between period of oscillation (cycle 2 in 3 insets) and delay. At data from all the subjects, these lines had slopes between 1.0 and 1.2 and intercepts between 0.2 and 0.3 s. Thus the period of oscillation was 200–300 ms greater than the total delay. The symbols at lower right in the insets indicate the monkey: ▲ for monkey I, ● for monkey J, and ■ for monkey N.

Figure from Goldreich, Krauzlis & Lisberger (1992).



Smooth pursuit of flicker-defined motion

Jeffrey B. Mulligan
NASA Ames Research Center

Scott B. Stevenson
University of Houston College of Optometry

BIG QUESTION:

Can we demonstrate a position-driven pursuit response for certain classes of stimuli?

Approach:

Delayed Visual Feedback
(see Background panel at left)

Motivation:

Previous work suggests pursuit responses combine signals from volunatry and reflexive pathways with different properties, which respond to different stimuli.

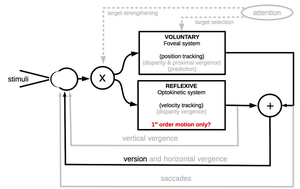
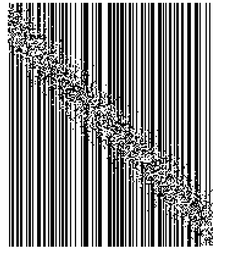


Figure from Mulligan, Stevenson & Cormack (2013), showing proposed architectural model of pursuit control system, with portions relevent to this poster highlighted.

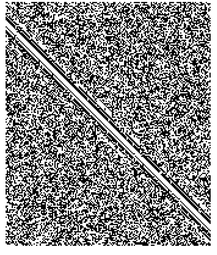
Stimuli

Space-time plots showing time (top-to-bottom), and one spatial dimension for the four classes of stimuli studied.

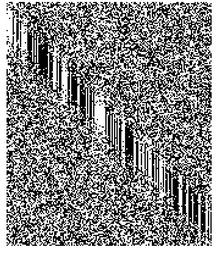
"black"



"twinkle"



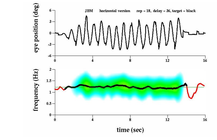
"rigid"



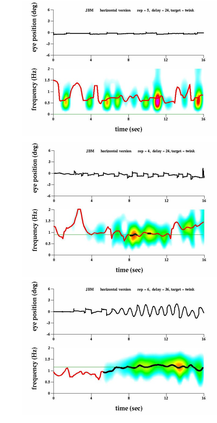
"static"

Trials

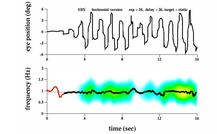
Vigorous oscillation seen with conventional target



Twinkle target oscillates only after learning



"Static" target show mixed response



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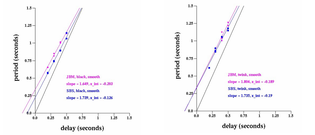

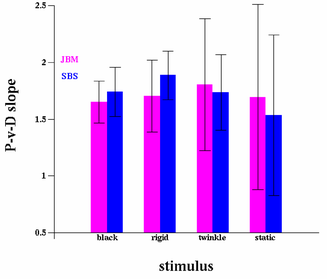

Conclusion

Can we demonstrate a position-Driven pursuit response for certain Classes of stimuli?

TODAY'S ANSWER: Not yet...

References

Goldreich, D., Krauzlis, R. J., and Lisberger, S. G. (1992). "Effect of changing feedback delay on spontaneous oscillations in smooth pursuit eye movements in monkeys." J. Neurophysiol., **67**(3), 625-638.

Mulligan, J. B., Stevenson, S. B., and Cormack, L. K. (2013). "Reflexive and voluntary control of smooth eye movements." in Rogowitz, B.E. Pappas, T.N., and de Ridder, H. (eds.), *Human Vision and Electronic Imaging XVIII*, Proc. SPIE, v. 8651.